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Evaluation of Ecological Flow and Concentrations of Pollutants in Selected River Basin in Eastern Slovakia

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Abstract

From the hydrological characteristics of the stream and river basins are particularly serious its extremes, that is, maximum and minimum flow rates and water levels. In the past, emphasis was placed on maximum discharges that occur in river basins and that are usually catastrophic. Currently, the emphasis is also put on the minimum flow rate - coupled with drought. Processing of the minimum (ecological) monthly discharges and their evaluation and trend lines is also the subject of this paper. Scientific aspect of the work is determination of minimum flow and also the evaluation of water quality through the concentration of pollutants in the water flow. Data were obtained from the Slovak Hydrometeorological Institute and include minimum monthly flow rates (for the period from 1995 to 2013) from river stations in Eastern Slovakia: Svit (river Poprad), Ižkovce (river Laborec), Košické Olšany (river Torysa) and concentrations of pollutants (P_{tot}, $N\text{-}NO_2$) from the same hydrometric stations for the same years. Concentrations of pollutants have decreasing trend (for almost all cases) in the monitored period.

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Keywords: pollutants; ecological flow; trend; eastern Slovakia

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1. Introduction

Changes in the natural environment taking place today are to a significant extent the result of human pressure. These changes are having an effect on water circulation and the flow of matter in river catchments. This is particularly clear in terms of the intensity and the frequency of extreme events such as floods and low flow events [1]. Given the economic and social consequences of extreme events, the study of such events has become an important issue in science [2,3,4]. The minimum (ecological) flow rate is the flow rate which must be secured in a stream that has not disturbed ecological status of a stream. Minimum flows also represent the maximum depletion of natural flows allowable without impairing the ecological services of rivers [5]. An environmental flow assessment produces one or more descriptions of possible modified hydrological regimes for the river; the environmental flow requirements, each linked to a predetermined objective in terms of the ecosystem´s future condition. For instance, these objectives may be directed at the maintenance or enhancement of the entire riverine ecosystem, including its various aquatic and riparian biota and components from source to sea, at maximizing the production of commercial fish species, at conserving particular endangered species, or protecting features of scientific, cultural or recreational value [6]. The majority of ecological flow methodologies described can be grouped into four reasonably distinct categories, namely hydrological, hydraulic rating, habitat simulation (or rating), and holistic methodologies, although differences in group classifications do occur among authors [7,8,9,10,11].

Processing of the ecological monthly discharges and their evaluation and trend lines is also the subject of this paper. Evaluation was done in three hydrometric stations in eastern Slovakia. Data were evaluated for the period from 1995 to 2013. Trend of concentrations of pollutants at the same hydrometric stations for the same time period were evaluated.

2. Methodology

Data used for the research were obtained from the Slovak Hydrometeorological Institute (SHMI). There were minimum monthly discharges at selected hydrometric stations Svit (river Poprad), Košické Olšany (river Torysa) and Ižkovce (river Laborec) and the concentration of pollutants in the mentioned river profiles. Specifically, these data are the minimum monthly discharges during the period from 1995 to 2013 and the concentrations of the pollutants in the water stream, namely concentrations of $N\text{-}NO_2$ - nitrite nitrogen and P_{tot} - total phosphorous. Location of river stations is shown in Fig. 1.

The limit values of concentrations are established by the rule no. 269/2010 Coll. - Regulation of the Government of the Slovak Republic, laying down the requirements to achieve good status of water bodies, namely Appendix 1 [12]. Limit concentrations of pollutants pursuant to this Regulation are 0.4 mg/L for P_{tot} and 0.02 mg/L for $N\text{-}NO_2$. Maximum permissible values of concentrations are marked by bold red horizontal line in the graphs in Figures 3, 4, 6, 7, 9 and 10.

Finally the statistical analysis – correlation dependency of minimum river discharge and concentrations of pollutants was done. The hypothesis was that the concentrations of P_{tot} and $N\text{-}NO_2$ are decreasing with decreasing river discharge.

3. Methodology

The following part is devoted to processing and evaluating the minimum monthly flow rates during 18 years (1995-2013) in the monitored hydrometric stations. The progress of minimum monthly flow rates have been processed into graphs, and also have been used to express the trend of these flow rates for each hydrometric stations at Poprad river, Torysa river and Laborec river.

3.1. Poprad river

Figure 2 shows the course of the minimum monthly flows in hydrometric station Svit at the Poprad river during the reporting period.

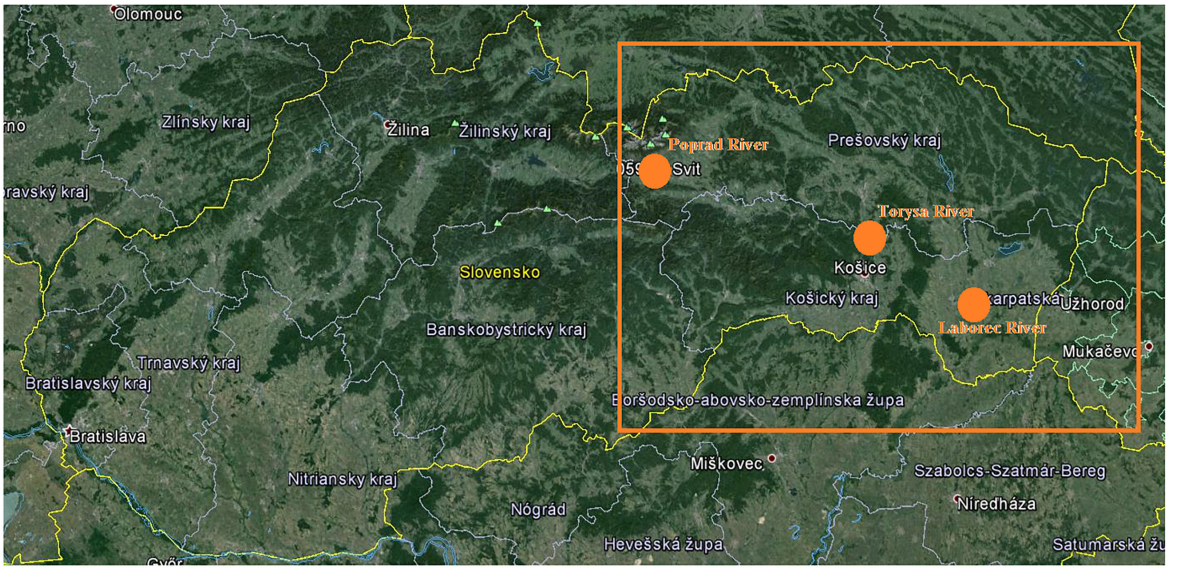

Fig. 1. Location of evaluated river stations in the eastern Slovakia.

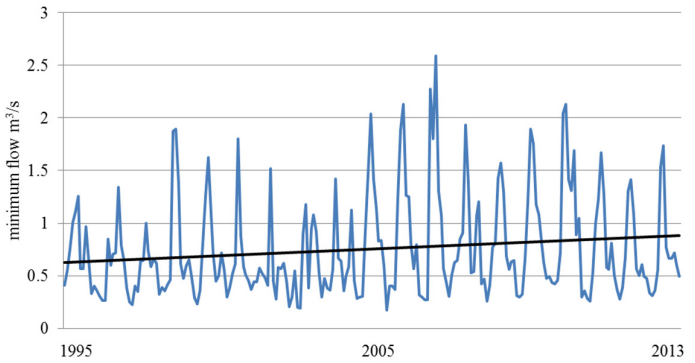

Fig. 2. Course of minimal discharge in river station Svit during the evaluated period.

The trend flowline of these flows have been used to express the trend on minimum flows.

Minimum monthly flow in river hydrometric station Svit is stable, resp. has slightly increasing trend as it is depicted in Fig. 2. The course of the minimum monthly flows is quite dependent on the season, because the river Poprad is near the High Tatras Mountain. The highest flow rates are achieved in the spring when the snow melting starts and during the rainy season, while the driest period is during the winter months.

The course of concentrations of $N\text{-}NO_2$ and $P_{tot.}$ in the hydrometric station Svit is presented in Figures 3 and 4. From Figures 3 and 4 it is apparent that a concentration of $P_{tot.}$ in hydrometric station has decreasing and concentration of $N\text{-}NO_2$ has significantly decreasing trend. Limit concentrations of $P_{tot.}$ (Fig. 3) are not surpassed (even marked at the graph; limit concentration is 0.4 mg/L), but limit concentration of $N\text{-}NO_2$ was surpassed few times till the 2003 year. Since that the situation was under control.

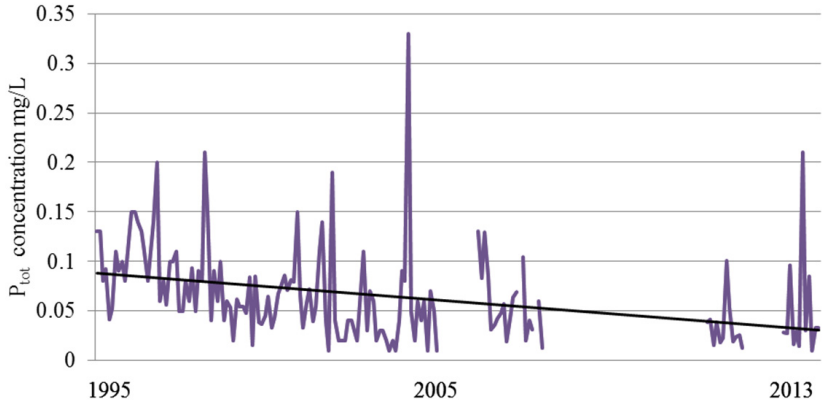

Fig. 3. Course of P_{tot}. concentration in hydrometric station Svit during the evaluated period.

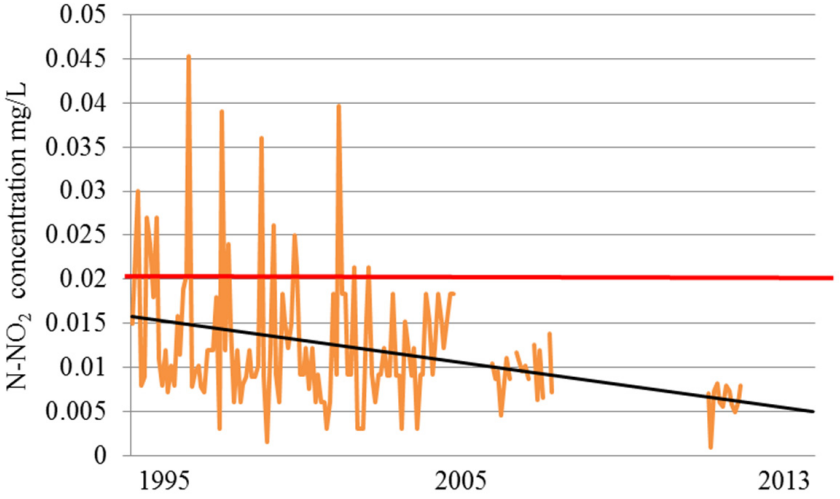

Fig. 4. Course of $N\text{-}NO_2$ concentration in hydrometric station Svit during the evaluated period.

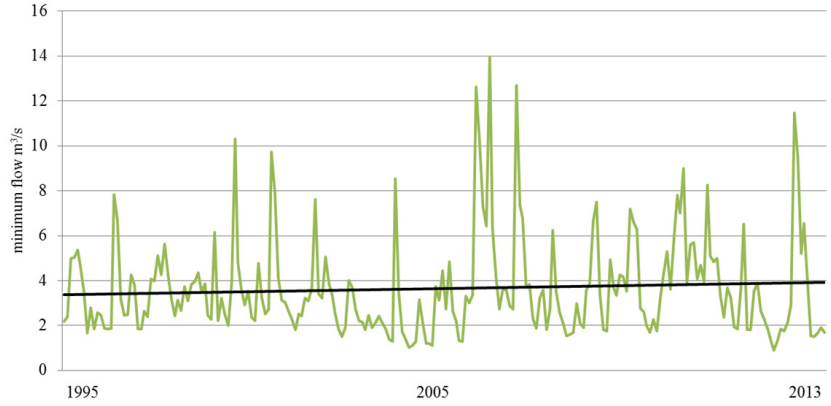

Fig. 5. Course of minimal discharge in river station Košické Olšany during the evaluated period.

3.2. Torysa river

The course of the minimum monthly discharges in hydrometric station Košické Olšany at the Torysa river during the reporting period and trend on minimum flows (expressed by the trend line) are presented in Figure 5.

Minimum monthly flow in river hydrometric station presented in Figure 5 (Košické Olšany) is stable with the very slight increase in time. In Figures 6 and 7 the concentrations of nitrite nitrogen and total phosphorous are depicted. Also the limited concentrations according to legislation are presented by horizontal red bold line.

As it is represented in Figures 6 and 7 the concentration of both evaluated pollutants has decreasing trend. Values of nitrite nitrogen are overwhelming above the limit (Fig. 7) while phosphorous total (Fig. 6) has sporadic overwhelming during the evaluated period.

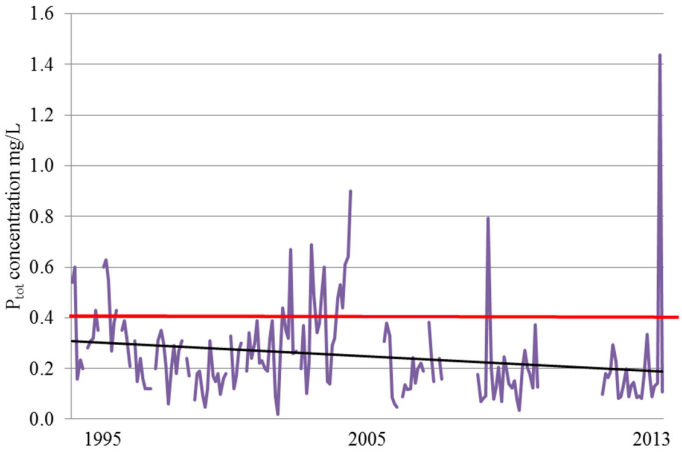

Fig. 6. Course of $P_{tot.}$ concentration in river station Košické Olšany during the evaluated period.

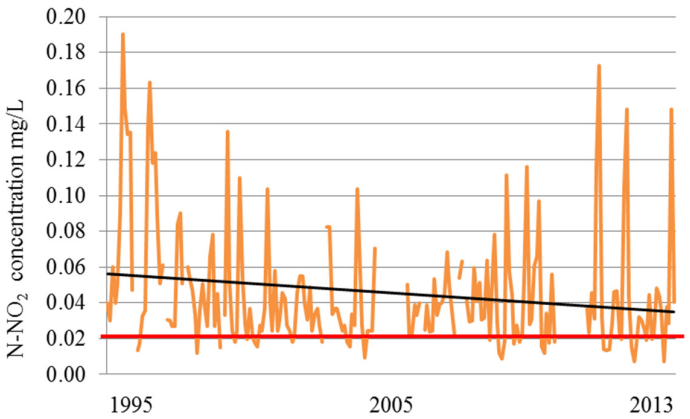

Fig. 7. Course of $N\text{-}NO_2$ concentration in station Košické Olšany during the evaluated period.

3.3. Laborec river

The course of the minimum monthly discharges in hydrometric station Ižkovce at the Laborec river during the reporting period is different than in hydrometric stations Svit and Košické Olšany. In this station the trend of minimum flow is slightly decreasing (Fig. 8).

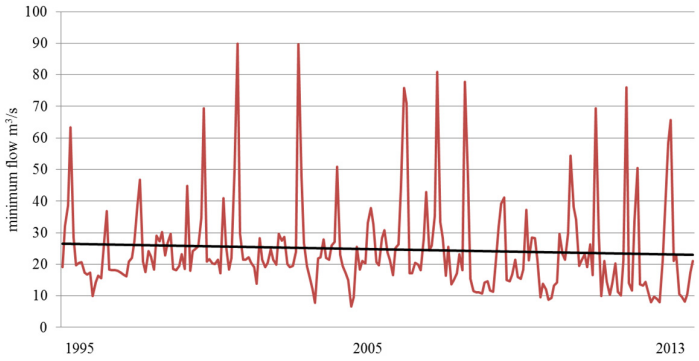

Fig. 8. Course of minimal discharge in river station Ižkovce during the evaluated period.

Minimum monthly flow in river hydrometric station presented in Figure 8 (Ižkovce) is decreasing. The minimum value of river flow was observed on September 29th, 2003 (Q_{min}=6.58 m^3/s) and the maximum flow was observed on April 30th, 2000 (Q_{min}=89.83 m^3/s) during the evaluated period.

In Figures 9 and 10 the concentrations of nitrite nitrogen and total phosphorous are depicted. Also the limited concentrations according to legislation are presented by horizontal red bold line in case of *N-NO*$_2$ (for the total phosphorous the limit concentration is out of range of the graph).

From Figure 9 is obvious that the value of $P_{tot.}$ concentration during the 18 years did not reach the limit value given by legislation even the trend of concentration measured in river is increasing. Different situation is for *N-NO*$_2$ where the trend is decreasing but its concentration is mostly about the limit value (Fig. 10). This river is highly polluted with nitrite nitrogen.

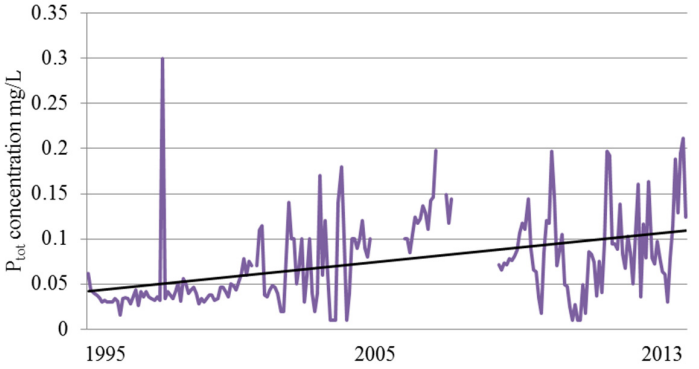

Fig. 9. Course of $P_{tot.}$ concentration in river station Ižkovce during the evaluated period.

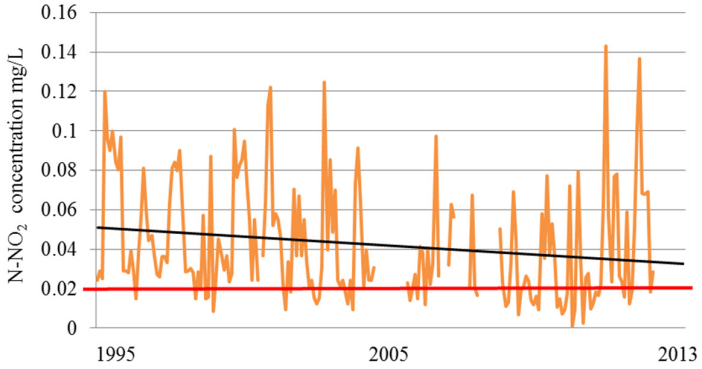

Fig. 10. Course of *N-NO*$_2$ concentration in river station Ižkovce during the evaluated period.

3.4. Correlation coefficient

The correlation coefficient was used for determination of the dependency between the monthly minimum flow and quality of water in the river. Concentrations of pollutants were compared with a minimum flow rate in hydrometric station Svit. The results are shown in Tab. 1.

Table 1. Correlation coefficient of pollutants and minimal flows in evaluated river station.

	Correlation coefficient	
pollutant/minimum flow	$P_{tot.}$ / Q_{min}	*N-NO*$_2$ / Q_{min}
Svit	0.25	0.06
Košické Olšany	0.32	0.07
Ižkovce	0.12	0.19

From the results presented in Table 1 it is evident that between the concentration of pollutants in the stream, and monthly minimum flow is very small or almost no dependency. Correlation coefficient achieved in all cases is a very low value (close to 0). Only in the case of *N-NH*$_2$ / Q_{min} in river station Košické Olšany the medium dependence was demonstrated. We cannot speak about any dependency, thus hypothesis that was uttered at the beginning of this work was not proven.

The future research

Refutation of this hypothesis is probably due to the time variation for measured monthly minimum flow rates and concentrations of pollutants in the stream. The concentrations of pollutants were measured in the specified date, regardless of when minimum flow rate has been achieved.

It is believed that this hypothesis will be confirmed when it will be determined a relationship between the concentrations of pollutants in the stream and the flow in the same day when the concentrations are stated. In this case it would likely be confirmed that at the lower achieved flow rates the concentrations of pollutants will be a higher values.

4. Conclusion

The article presents the evaluation of trends of minimum monthly discharges and concentrations of P_{tot} and *N-NO*$_2$ in three river stations at three different rivers in the eastern Slovakia, namely river Poprad (river station Svit), river Laborec (river station Ižkovce) and river Torysa (river station Košické Olšany). The results show that the minimum flow rate in eastern Slovakia has increasing trend at rivers Poprad and Torysa, while on the river Laborec, the trend is

slightly decreasing. The next part of the paper is aimed on evaluation of the trend of P_{tot} and $N\text{-}NO_2$ concentrations in selected river stations. Torysa River (station Košické Olšany) where the highest concentrations of all pollutants were measured is the most polluted water course. The least polluted is river Poprad, which is related to the fact that hydrometric station in Svit is located at the upper part of the river and there is not so intense agricultural activity in the catchment area. Most exceeded limit concentrations were monitored for pollutant nitrite nitrogen ($N\text{-}NO_2$). For all pollutants and hydrometric stations, however, the decreasing trends of monitored pollutants were shown, except P_{tot} in river station Ižkovce. It is mainly due to stricter standards for industry and agriculture, as well as a growing network of public sewage systems that are connected to a water treatment plant also in small villages, which limits direct discharges pollutants to the recipient.

Acknowledgements

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[12] SR Government Regulation 269/2010 Coll. which stipulates criteria for achieving good water balance, laying down the requirements to achieve good status of water bodies (Appendix 1).